SOIL CONSERVATION

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This corn on the farm of J. J. Lydeck, near Craig, Nebr., is protected on the south by a tall windbreak planting and will yield from 60 to 70 bushels per acre.

Windbreaks Help Control Erosion in the Great Plains

By George W. Hood [1]

THE VALUE of trees in the Great Plains has been recognized for more than a hundred years. During that time, millions of shrubs and trees were planted. In pioneer days they were considered an essential feature of the prairie home. They protected the farmsteads from the chilling winds and drifting snows of winter and checked the withering blasts of hot, dry summer. Trees increased the value of prairie and plains farms.

Many good things are not understood until they are lost, and so it has been with the trees. During the past few years large numbers of the trees on the Great Plains have perished because of adverse weather conditions, drought, and grasshopper injury. Many others disappeared because they had reached their natural span of life and farmers did not realize that trees require maintenance just as do other types of farm investment. A farm windbreak, for example, once it is established, requires care and management if it is to be permanent. Trees mature and die and must be replaced by new plantings and this must be followed up with cultivation and thinnings. The life cycle of birth, growth, and decay applies to trees as to all living things and on the plains artificial replacement often must take the place of natural reproduction which under more favorable conditions for tree growth, is Nature's method of perpetuation.

The early settlers on the plains migrated from the East. Trees were a part of their life, and when they moved to the plains their first impulse was to plant

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trees. Such plantings were early recognized as protection to the home and stock but it was some years before the farmers realized their value as shields for fields planted to crops and that their use resulted in increased yields. This benefit from windbreaks is now fully recognized.

Perhaps no better example of the beneficent influence of windbreaks can be found than that on the farm of J. J. Lydeck near Craig, Nebr. The windbreaks are multiple rows of mixed deciduous and coniferous species. They are over 25 years old, and their positive influence has been proved by the regular yearly yields on the protected areas. During the drought of 1934, without irrigation, Mr. Lydeck's potatoes yielded 250 bushels and his corn 40 bushels per acre, while on all sides, for many miles, crops were burned up by the hot winds which daily swept the area. In the drought of 1936 Mr. Lydeck's oats produced 25 bushels per acre in these protected areas, while his neighbors harvested but 5 bushels on the wind-swept prairie. His orchard likewise was loaded with fruit of excellent quality. Even in normal years the crops from the fields protected by his excellent windbreaks nearly double those on the unsheltered areas.

In the Great Plains we sometimes hear this remark: "I don't want any windbreaks. I don't have any room for trees; they take up too much ground from my crops. They sap the soil of food and moisture and I can't plant my crops out to the fence line." Such statements are not confined to our dirt farmers, but now and then come from farm leaders whose function it is to educate and direct agricultural thinking.

Mr. Lydeck has devoted many acres of his farm to windbreak plantings. He has had protection from the wind and his yields have been consistent and uniform year after year. The windbreaks have increased the value of his farm: It would sell for perhaps double the price of any other farm within miles. But it is not for sale. It is a profitable farm, and the home of a contented family.

Recently James Kring, forester of the Ralston project, reported on a corn field near David City, Nebr., which was protected from the hot, dry, south wind by a windbreak. Four acres were selected for measurement and the area divided into four plots. One hundred feet of corn row was measured off in each plot. The recorded yields are as follows:

Plot No. 1 was protected from the south by a windbreak of trees, and produced 32 pounds of corn per hundred feet of row (about 55 bushels per acre).

Plot No. 2 was located 300 feet north of plot No. 1, and produced 14 pounds per hundred feet (about 25 bushels per acre).

Plot No. 3 was 600 feet north of plot No. 1, and produced 9 pounds of corn (about 16 bushels per acre).

Plot No. 4 was 2,000 feet from No. 1, was out of range of any protection from the windbreak, and produced only 4 pounds of corn (about 7 bushels per acre).

Establishment of Windbreaks

In the Great Plains the proper methods for establishing windbreaks differ somewhat from those followed in other areas. The hot, dry winds, together with the limited moisture, exert a definite influence on small trees just as on other plants, with the possible exception that, with good nursery stock and proper site preparation and care for the first few years, trees can be established when other crops fail. The loss of trees in windbreak plantings in the Great Plains has been due largely to improper site preparation, poor care, inferior nursery stock, and grasshopper damage. The adverse climatic factors can be overcome; trees will grow and even flourish if given the necessary care and attention.

Preliminary Steps

Success in establishing a windbreak stand cannot be expected if the seedlings are merely planted without preparation of the soil and then abandoned. All sites should be either completely plowed or, if this is impossible, two or three furrows should be plowed and the trees set in the prepared strip. From three to five cultivations a year should be given the plants, and this should continue until it is impossible to pass through the trees.

Windbreaks can be planted either on the contour or in straight lines. Except in those areas which are level and sandy, the windbreaks should be laid out on the contour—this for reasons other than protection. A contour planting establishes a permanent guide line to be followed in farm operations which is better for the conservation of soil and water than straight lines up and down slopes, even though the grade is very slight. In the wheat belt where the land is practically level there may be certain advantages in planting along the section lines.

Composition

Formerly a windbreak meant one row of trees, but that conception has changed in recent years; we now think of a windbreak as consisting of more than a single row of plants. The composition and width are important factors. To be most effective, deciduous trees, evergreen trees, and shrubs are essential. Windbreaks

Cultivating young honey locust and Chinese elm trees in a woodland and windbreak planting. It is desirable in such a planting to keep out weeds and obnoxious plants.

composed of any one of the groups will be effective to a degree and have a place in certain types of protection. It has been demonstrated that one row of shrubs planted at close intervals is effective in nursery practice, and that one row of trees will give some protection to crops. But to build good windbreaks—taking into consideration the ecological factors of tree growth—a combination of all three groups is to be preferred.

The number of rows to be planted must be decided by the farmer and his decision should be based upon several factors, namely, the size of the farm, type of farming, areas to be protected, kinds of crops, number of livestock and other local conditions. From an ecological standpoint, the multiple-row windbreak, varying from 10 to 20 rows of trees and shrubs, is preferred because such plantations simulate a natural forest with an accumulation of ground litter—better soil moisture conditions. In the snow country, the wider windbreaks also collect snow and thus additional moisture is made available to the trees. Beneficial results are secured, however, from one row of plants up to the maximum number practicable to the particular location.

Spacing

The proper spacing of the plants is a subject so controversial, due to the many variations of soil, rainfall, wind velocity, object of planting and other local conditions, that specific recommendations are almost impossible. There should be some variation according to the species used, although the earlier windbreaks were not planted with this in mind. Practically all the multiple plantings were approximately 4 feet by 4 feet. Hedges of Osage orange were spaced 1 foot apart in a single row bordering a field, and many miles of these hedges are still alive and thrifty.

In other parts of the Great Plains, plantings have been variously spaced—from 2 by 4 up to 18 by 20 feet. It is my opinion that a spacing that is too wide is as bad as one that is too close. The close spacing injures and kills out the trees, while the wider spacing doesn't produce a windbreak of any value over a long period. It seems logical that a modified spacing between the two extremes, together with proper silvicultural management, gives the quickest and most effective results. Where close planting is practiced, thinning should be done at the proper time. The whole aim in developing a windbreak is to keep a solid bank of foliage from the ground to the top and therefore the side branches must not be allowed to die. As soon as the branches touch, the thinning should be done. This is particularly applicable to conifers but much less so to deciduous trees.

Since it is essential that the plantings be cultivated, the spacing should be regulated according to the kind of cultivating implements available. To develop a multiple row shelterbelt, three groups of plants are desirable: First, the outer group, consisting of one to three rows of close-growing shrubs which hold their foliage to the ground and form a dense wall; second, the intermediate group, or medium-sized plants adjacent to the shrubs; third, the group of taller trees, which are placed next to the medium-sized group, and which will determine the height and therefore the scope of its effective influence. If this arrangement is used on both sides, a high center, sloping both ways, will be the result.

From my observation of plantings the following general rule for spacings may be considered satisfactory: Rows 7 to 10 feet apart, and the plants in the row 4 to 8 feet apart. In most windbreaks the rows may be a uniform distance apart. The outer border of shrubs can be spaced 4 to 6 feet in the row (some foresters advocate planting caragana 1 foot apart on the

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Humus and Soil Conservation

By Selman A. Waksman [1]

AMONG the various factors which markedly influence the conservation of the fertility of our soils as well as of the very soils themselves, none is more important than the abundance and nature of the soil organic matter or the soil humus. Its presence is very characteristic of the soil and distinguishes it from a mass of disintegrated rock material. Humus serves a most important role in soil formation, in the process of weathering, and gives the characteristic nature to the soil profile. It improves the physical condition of the soil, by increasing its moisture-holding capacity, by favoring better aeration, and by creating a better soil structure. It improves the chemical condition of the soil, by serving as a storehouse of plant nutrients and by rendering some of the inorganic elements more readily available to the plant, thus making the soil more fertile; it improves the buffering capacity of the soil, or its ability to avoid rapid changes in reaction to acidity and alkalinity; it also serves to neutralize toxic conditions of the soil as a result of extensive cultivation or use of excessive amounts of artificial fertilizers. It improves the soil as a medium for the growth of micro-organisms, which bring about numerous processes highly important for plant nutrition. Finally, it makes the soil a better substrate for the growth of our cultivated and uncultivated crops. In general, humus exerts a most controlling effect upon the soil and its fertility; without humus, the surface layer of the earth could hardly be designated as a soil in a true sense. The conservation of the soil humus may, therefore, truly be considered as of the greatest importance for soil fertility and crop production.

Although so highly significant in the soil and in soil processes, humus constitutes, in the majority of soils, only a small fraction of the total body of the soil. The actual amount of humus found in any soil depends upon soil type, land topography, vegetation, and treatment. It varies from about 0.5 percent or even less, for the very poor sandy soils, to 5, 6, and even 12 percent in the case of the prairie soils. The humus content may be even higher in soils formed from peat bogs. The humus is usually concentrated in the upper soil layer or horizon and diminishes rapidly in the subsoil (fig. 1).

The term "humus" is used to designate all organic matter found in the soil, as well as that organic matter

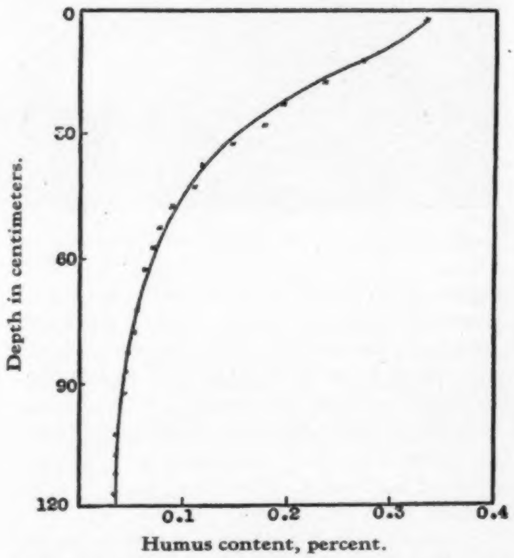

Figure 1.—*Humus distribution with depth of a Carrington silt loam, Nebraska (after Russell and Engle).*

which is produced, through the agency of microbes, in the decomposition of plant and animal wastes in soils, in composts and in the disposal of sewage and garbage. Plants and plant residues form the all-important sources of humus, either directly, as in the case of roots, stubble, leaves, composts and green manures, or indirectly, after the plant products have become digested by the animals and have become partly converted into animal substance, which in itself will sooner or later become a source of humus. Straw or leaves, horse manure or cow manure, earthworms or beetles are not yet humus; however, after they have become partly digested by the numerous soil inhabiting microbes, they are gradually converted into a dark-colored, amorphous mass, which is humus.

In order to determine the chemical nature of humus and recognize the processes which lead to its formation, it is necessary first of all to know the chemical composition of the plant materials from which it is formed. These materials, whether left as residues from cultivated and uncultivated crops, or grown specially as sources of humus in the form of green manures, are not uniform in chemical composition. They comprise a number of compounds, which are decomposed by the soil microbes with different degrees of rapidity.

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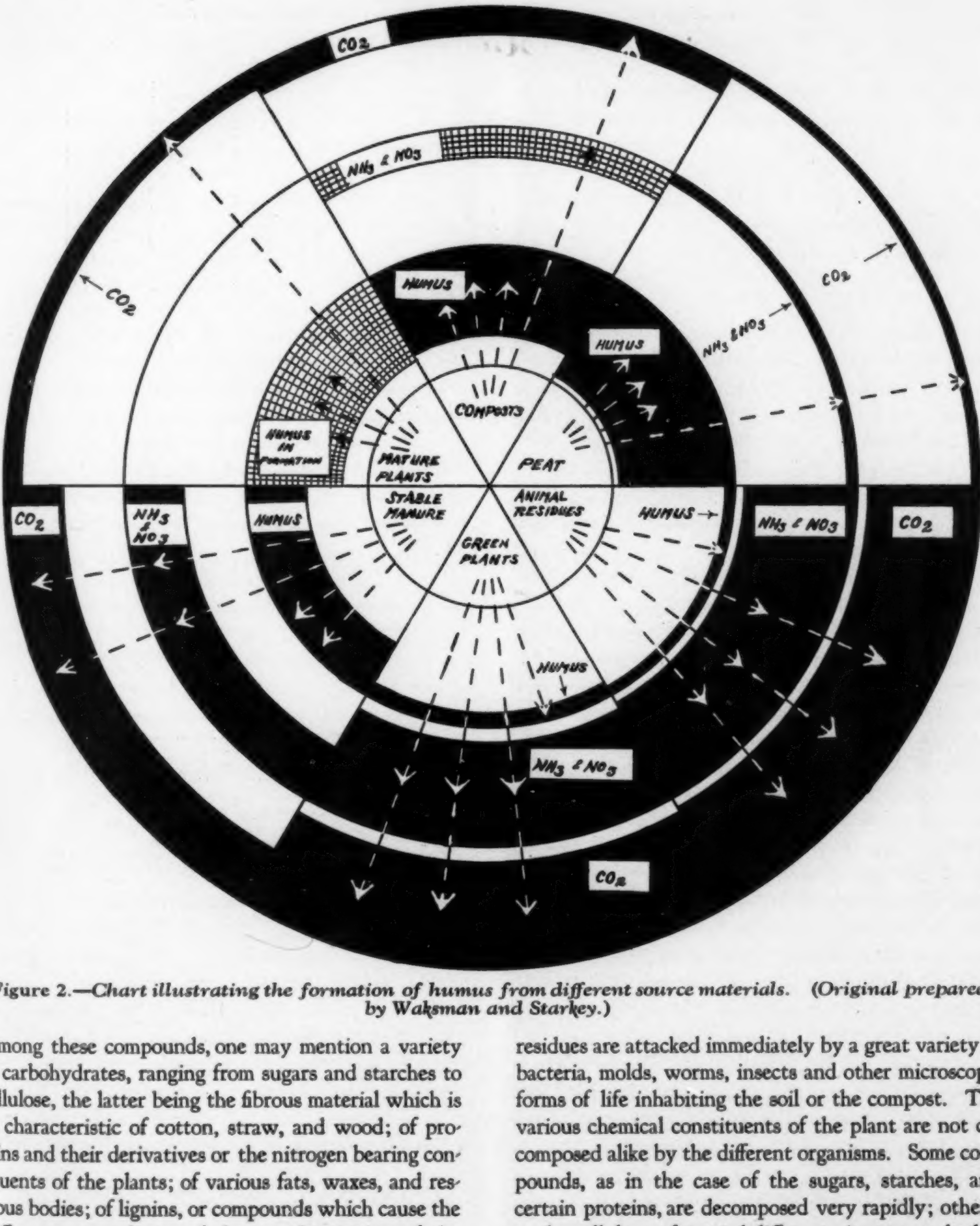

Figure 2.—*Chart illustrating the formation of humus from different source materials. (Original prepared by Waksman and Starkey.)*

Among these compounds, one may mention a variety of carbohydrates, ranging from sugars and starches to cellulose, the latter being the fibrous material which is so characteristic of cotton, straw, and wood; of proteins and their derivatives or the nitrogen bearing constituents of the plants; of various fats, waxes, and resinous bodies; of lignins, or compounds which cause the stiffness or woodiness of the woody portion of the plants; of mineral elements and salts, some of which are soluble in water and others insoluble; finally, of a variety of chemical compounds, which vary in nature and in abundance, depending upon the kind of plant, its age and conditions of growth.

When placed in the soil or in a compost, the plant residues are attacked immediately by a great variety of bacteria, molds, worms, insects and other microscopic forms of life inhabiting the soil or the compost. The various chemical constituents of the plant are not decomposed alike by the different organisms. Some compounds, as in the case of the sugars, starches, and certain proteins, are decomposed very rapidly; others, as the celluloses, fats, and different nitrogenous bodies are attacked more slowly; still others, like the lignins, waxes, and resins, are highly resistant to decomposition. The micro-organisms themselves are highly specialized in their choice of nutrients: some prefer to decompose certain chemical compounds and some are able to attack others; certain organisms develop first on the

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Table 1.—*Chemical composition of rye plant at different stages of growth*

[Percent basis of dry material]

Stage of plant growth [1]	Cold water soluble constituents: Total soluble	Cold water soluble constituents: Soluble carbohydrates	Cold water soluble constituents: Minerals	Cellular carbohydrates	Lignin	Total nitrogen	Total minerals
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
I. 10-14 inches high	34.2	3.5	5.1	34.7	9.1	2.50	7.7
II. Just before heads begin to form	22.7	6.0	4.6	48.2	11.8	1.86	5.9
III. Just before bloom	18.2	2.8	2.4	53.3	18.0	1.01	4.9
IV. Mature plants	9.9	2.1	2.1	59.2	19.8	.24	3.9

[1] In the case of III and IV, only stems and leaves were used.

fresh residues, while others follow; some grow under certain soil conditions, as influenced by reaction, temperature, aeration, water supply, etc., while other organisms develop under other conditions. As a result of the influence of these various factors, namely the nature of the plant residues, the nature of the microorganisms and the conditions of decomposition, the resulting humus will vary considerably in abundance and in chemical composition.

The processes of decomposition of the complex plant constituents are frequently designated as "decay," "mineralization," "humification;" they do not result in the complete destruction of these compounds, but lead to the formation of various volatile and nonvolatile products. These include carbon dioxide, ammonia, phosphates, sulphates, and others; the ammonia is rapidly oxidized by certain organisms to nitrate. The various microbes bringing about the decomposition of the plant residues will build up a considerable amount of cell substance as a result of their extensive multiplication. The synthesized material consisting of proteins, carbohydrates, fats, etc., may amount to as much as 10 to 30 percent of the decomposed residues. The new compounds together with the resistant undecomposed portions of the plant and animal residues form the major part of the humus in soils and in composts.

Humus Formation at Different Stages

In order to illustrate the above processes, it is sufficient to cite certain experiments, carried out at the New Jersey station, on the formation of humus in the decomposition of rye plants, harvested at different stages of growth. Table 1 shows the chemical composition of these plants, table 2 the rapidity of their decomposition, as measured by carbon dioxide evolution, and table 3 the amount and nature of humus produced from young and mature plant material. When the plants are young they are rich in water soluble minerals, in soluble carbohydrates and in nitrogenous substances. As they grow older, these diminish, while the cellular substances, especially the fibrous materials and the lignins or woody bodies, increase.

The changes in the chemical composition of the growing plant have an important influence upon the rate of their decomposition and upon the products formed. The younger the plant, the more rapidly it decomposes and the less humus is formed. Among the different products of decomposition, none is more

Table 2.—*Decomposition of rye plants at different stages of growth*[1]

[2 grams of dry material added to soil]

Stage of plant growth	Carbon dioxide given off	Nitrogen liberated or consumed
	Milligrams	*Milligrams* [2]
I	286.8	+22.2
II	280.4	+3.0
III	199.5	−7.5
IV	187.9	−8.9

[1] Period of decomposition 27 days.
[2] + indicates that nitrogen was liberated as ammonia, which was then oxidized to nitrate. − indicates that nitrogen was required in order that the organisms could decompose these materials; without added nitrogen, the rate of decomposition, as measured by evolution of carbon dioxide, would have been even slower.

Table 3.—*Humus formation from young rye plants and from mature rye straw*

Stage of plant growth	Days of decomposition	Total organic matter left	Total cellular carbohydrates left	Lignin left	Protein left
		Percent	*Percent*	*Percent*	*Percent*
Young plants (second stage)	30	27.0	21.0	63.6	31.0
Mature plants (fourth stage)	60	58	41.8	88.7	[1] 286.7

[1] The increase in protein is due to its being built up by the micro-organisms decomposing the straw; this accounts for the nitrogen consumption reported in table 2.

Table 4.—*Influence of fertilization upon the humus content of the soil*

Soil treatment	Humus content	Nitrogen content
	Percent	*Percent*
No manure since 1843	1.50	0.10
Stable manure since 1852	4.92	.26
Complete artificial fertilizers (ammonium sulphate)	1.69	.10
Complete artificial fertilizer plus stable manure	5.38	.25
Potash and phosphate only, no nitrogen	1.65	.09

important than the nitrogen. The decomposition of the younger plants results in the liberation of some of the nitrogen as ammonia. In this experiment, 44 percent of the nitrogen was liberated in 27 days from the youngest plants. On the other hand, in the decomposition of mature plants, no nitrogen was set free; actually rapid decomposition of the plant and its transformation into humus required additional inorganic nitrogen. This is a practice usually employed in the preparation of composts from straw. There is a certain stage in the growth of the plant, namely when it contains about 1.5 percent to 1.7 percent nitrogen, when the plant material decomposes readily, without liberating nitrogen and without requiring any added nitrogen. After some period of time, the humus itself will gradually decompose and the nitrogen will become slowly liberated.

The results reported in table 3 show definitely how the amount of humus left depends upon the age and nature of the plant. The young rye plants, after 30 days decomposition, left only 27 percent of the organic matter as humus. The mature plants, however, even after 60 days of decomposition, left more than double that amount of humus. In the case of the young plants, only a third of the nitrogen was left in the humus and two-thirds were made available, while in the mature plants, the humus contained three times as much nitrogen as the plant itself. This nitrogen was obtained from added mineral sources.

Sources of Humus

The amount of humus formed in the decomposition of plant materials is thus shown to depend, primarily, upon the chemical composition of these materials. Vague generalizations are usually made concerning the amount of humus left in the soil as a result of the addition of different plant and animal substances which serve as sources of humus. In order to place this information in as comparative a manner as possible, especially for the purpose of illustrating the relation between decomposition and humus formation, a special chart is presented here (fig. 2).

This chart shows that the various sources of humus can be divided into several overlapping groups: 1. Some materials, like green plants and animal residues, decompose rapidly, leaving comparatively little humus; this is accompanied by a rapid liberation of the nitrogen and of the mineral elements in available forms. 2. Other materials like peats, which have already undergone extensive decomposition, are largely in a humus state and decompose only very slowly; however, the indiscriminate use of these sources of humus, except for very special conditions such as lawns and nursery beds cannot be recommended without certain modifications. 3. Animal manures and composts of plant residues form ideal sources of humus, since they gradually decompose, liberating some of the nutrients in a form available for plant growth and leaving considerable humus in the soil. 4. Mature plant materials, such as straw, leaves of trees and needles, decompose and form humus very slowly. No nitrogen is liberated before a considerable period of time has elapsed. The addition of nitrogen to soil may be required for the rapid decomposition of these materials; otherwise, the micro-organisms will compete with the growing plants for the nitrogen needed by them in the decomposition of these nitrogen-poor materials.

Humus and Soil Conservation

The gradual deterioration of the soil, as a result of cultivation or as a result of wind and water erosion, is always associated with losses of organic matter. These losses can serve as direct measures of the losses in soil fertility. Before the introduction of artificial fertilizers and before the systematic utilization of legumes in crop rotations, man depended entirely upon reserves of soil humus for his crop nutrients. These were made available through the slow and gradual decomposition of the humus by the countless micro-organisms inhabiting the soil. However, too often even now man still depends upon these reserves for the major portion of the nutrient requirements of his crops. Humus has been provided by nature to serve as the ever-normal granary for mankind upon which he can draw for his countless crops. One cannot afford, therefore, to continue to use up the humus without definite provision for its replacement.

It has been calculated, for example, that as a result of cultivation over a period of 60 years, soils in a non-eroded condition lost one-third of their total fertility, the losses being much greater during the earlier than the later periods. In the case of dry land farming, the losses may be even greater. It has further been calculated that virgin soil taken under cultivation lost in a period of 50 years as much organic matter as had been accumulated during the previous 5,000 years. When erosion also becomes a factor the losses in organic matter become even greater, since the humus is largely concentrated in the upper layers of the soil, as shown in figure 1. These layers are the ones to be removed by wind or water. Drifts and dust were found to contain much more humus than the residual soil.

It is now generally recognized that in order to prevent soil deterioration by water and wind erosion, the

ntroduction of organic matter is particularly necessary. Soil conservation, from a broad point of view, thus includes the conservation of the organic matter of the soil or the introduction of fresh supplies into the soil where the supply has become depleted. This may be brought about by putting large areas of land under grass, by plowing under special crops in the form of green manures and crop residues, and by the actual introduction of organic matter in the form of stable manures, artificial composts, or peats. The particular method employed must be determined on the basis of local conditions, nature and value of crops, and other factors.

It was concluded, on the basis of numerous experiments carried out in this country and abroad, that continuous cropping even under good management and fertilizer treatment tends toward a depletion of the organic matter of the soil. With heavy applications of farm manure the content of organic matter may be gradually increased over a period of years. When compared with corresponding soils not cropped and fertilized, soils continuously cropped, even if fertilized, showed a gradual loss of organic matter. It is sufficient to cite one of the classical experiments carried out at the Rothamsted and Woburn Experimental Stations in England (table 4).

In addition to stable manures and composts, the proper use of green manures, including cover crops, is capable of maintaining the soil organic matter and the soil nitrogen and of improving the physical condition of the soil, enhancing its water-holding capacity, and preventing excessive erosion. Green manures are utilized for four distinct purposes: (*a*) The conservation of the plant nutrients, (*b*) rendering the nitrogen available for the next crop, (*c*) addition of organic matter to the soil, and (*d*) increasing the supply of nitrogen in the soil through nitrogen fixation.

In summarizing the importance of humus in the soil, it is sufficient to point out its four major functions, namely, (1) in soil weathering, or the formation of a soil from the inorganic rock fractions; (2) in soil fertility, acting as a storehouse of nutrients for plant growth; (3) in improving the physical, chemical and biological soil conditions, thus making the soil a favorable medium for the growth of plants and microorganisms; (4) finally, in soil conservation, through improvement of the water-holding capacity, base-exchange capacity, nutrient-holding capacity, and other properties of the soil.

The humus of the soil fully deserves, therefore, to replace the time-worn expression "the fat of the land," since it is synonymous with it.

WINDBREAKS HELP CONTROL

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outside row) depending upon the species used, while the larger-growing trees should be spaced 6 to 8 feet in rows. Silvicultural management is essential even with this spacing, and thinning should be taken care of when trees crowd.

A combination windbreak and post lot planting should prove valuable as such a planting would produce a crop of fence posts at thinning time. By carefully planning the composition, black locust or catalpa might be a part of the original planting. It could be so spaced that at the time of thinning the post trees could be removed without lessening the effectiveness of the windbreak.

Species

The relative position of any species depends on the type of windbreak planned. Where three or four rows of plants are used to develop a low shelter, the largest plants may be chosen from those used in the outer rows of a tall windbreak. Or, where desired, the so-called intermediate trees may be the tallest in the group.

The variation in growth in a species in different localities may also change its position in the windbreak. The Osage orange is generally considered a medium-sized tree—this because the close planting which is practiced has checked its development. In most plantings the Osage is located rather close to the border of the windbreak. Many trees can be found that will reach the height of ash and cottonwood and a girth of 32 inches, and these could well occupy the tallest section of any windbreak. Variation in growth is also true of the Chinese elm. The Russian olive is another species which is generally considered a medium-sized tree and is used in borders.

The American elm and the Russian olive may occupy different positions in different windbreaks, their positions based on local conditions. But here again, it is not difficult to find trees that will grow as tall as the American elm and develop a girth of 36 inches.

Therefore, since a given position in a windbreak is relative and depends on local conditions, it is impossible to make definite recommendations for the placing of species until the type of windbreak desired is thoroughly understood along with the soil, climate and rainfall of the location.

The species suitable for plantings vary somewhat in the different latitudes and are rather limited. Trees valuable for windbreaks—their positions depending on

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Wind intensifiers made of boards and galvanized iron and placed on top of dunes. Foreground, badly eroded area; a dune 26 feet high, in background.

Research Contributions to Wind Erosion Control

By H. H. Finnell [1]

AT THE outset of wind-erosion control work in the southern plains in 1934 a thorough canvass of published and unpublished experimental data of the local experiment stations was made. Very few, if any, studies had been conducted directly on the subject of wind action, its fundamental causes and its effects upon the soil. It was generally observed that wind erosion occurred more frequently after long droughts and that active erosion was apparent after heavy rains when but a paper-thin crust of the surface soil had dried. Nevertheless, in the various stations many useful facts bearing indirectly upon and contributing to the planning of a preventive program were revealed as well as certain indicative leads which proved quite useful.

The information that proved most significant may be summarized as follows:

Ridged, cloddy, or trashy surface exposures resisted wind action. Certain kinds of plant residues were more effective than others and endured longer. The effects of tillage without trash were relatively temporary. Erosion became very difficult to control after two or more seasons of crop failure. Much evidence showed that rotations were not dependable through the hazards of erratic seasonal conditions, although there was a very meager evidence of possibilities for increasing the dependability of crops by manipulation of sequence. Even on the best wheat lands sorghums for grain or forage production exhibited a higher degree of dependability than wheat or other small grains. Studies of relations of various factors, particularly initial moisture and soil conditions, to crop production were in progress. The first results of run-off water conservation upon the amount and regularity of production of adapted crops were being observed. Preliminary observations of the semiarid soil nitrogen cycle and factors governing it were available. Studies of moisture relations and the disposition of rainfall as applied to a few specific soils and slopes were available. Climatological data over periods of from 20 to 60 years, but from widely scattered points, were available for most of the area.

In 1933 and 1934 the consequences of prolonged drought became acute over sections of the area and it was apparent that emergency tillage was no longer adequate for the control of wind erosion. At the same time all evidence plainly indicated the prime importance of growing vegetation and wind-resistant residue as reliable safeguards. Thus it was that vegetation became the basis of the permanent program of demonstration projects of Region 6. Almost all the methods applied since the inception of the program have had as their direct or indirect objective the obtaining and utilizing of vegetation for erosion prevention. The application of control methods to various problem areas is guided by consideration of (1) efficient land use, (2) efficient water use, (3) adequate safeguards against soil wastage.

A pointed example of handling a complex requirement may be observed in the conservation program developed for problem area 2B, the southern plains

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heavy wheatlands. The interdependence of the methods applied as relative to the objectives sought is interesting, and from a practical standpoint is conducive to a self-sustaining program. On the deep heavy soils of this problem area the infiltration rate is slow, and in spite of the gentle slopes considerable waste of surface waters was experienced during rains of high intensity. Research has revealed valuable possibilities of improving the efficiency of moisture utilization by means of contour tillage and terracing with results pointing to increase both in amount and dependability of production. The application of this information not only profitably develops a hitherto neglected resource, but contributes directly to the amount of ground cover and the regularity of its renewal.

A further contribution to the continuity of cropping, which is highly important in maintaining an adequate surface trash supply for erosion prevention, has been made by experimental studies of rotations and cropping systems. The useful information on this subject is both negative and positive. Systematic rotations were found inadequate to maintain an even flow of production or to improve soil fertility under semiarid plains conditions. At the same time, studies of the factors governing wheat production provided a basis of foreseeing production possibilities with sufficient accuracy to permit the practical planning of a variable cropping program to serve the purpose of and take the place of the unworkable systematic rotation. This variable cropping plan requires the introduction of sorghum crops, thus serving a double purpose—the utilization of current moisture and fertility resources which normally go to waste under a system of straight wheat farming, and the filling of intervals unfavorable to wheat production during which the land would otherwise be devoid of protective cover.

General experience and observation have emphazised the necessity of regularly returning a large amount of erosion-resistant crop residue to the land as a safeguard against wind-erosion hazards, but research has pointed out a further utilization of this material to maintain a high state of fertility. Soil and seasonal conditions unfavorable to legume crops, but favorable to free living organisms for the fixation of atmospheric nitrogen, necessitate dependence upon the latter for the maintenance of the nitrogen cycle. A high lime content, a plentiful supply of highly available phosphorous, and a normal freedom of the soil from leaching losses provide the natural conditions for an adequate nitrogen income with but one addition necessary on the part of soil management. A wide nitrogen-carbon ratio is essential to stimulate fixation, and this can be regularly provided by the gradual working into the soil of the carbonaceous residue left from such erosion-resistant crops as small grains and sorghums. Crop residues saved from grazing and from burning serve first to protect the surface from exposure to wind erosion, and finally to provide the wide nitrogen-carbon ratio essential to adequate nitrogen income.

The low rainfall efficiently utilized is a positive advantage to easy fertility maintenance, but skilled crop management to avoid lengthy periods of idleness are essential. It is important, in order to achieve the highest degree of soil conservation and economic stability, that soil moisture accumulations be used before they penetrate beyond the root zone.

The present ill repute of this area is not fundamentally due to the long drought period or to other unfavorable natural conditions. It could be more justly charged to the extremely low efficiency of the water-utilization and crop-management methods practiced. The natural conditions are favorable to a permanent agriculture. The corrections most needed are not so much changes in land use as changes in farming methods.

In the several other problem areas of Region 6 many different problem complexes present themselves. However, none of the needs can be successfully dealt with until the leaders of agriculture begin to observe the specific pertinent facts of the region and bend their efforts to work with rather than against natural conditions. To observe more adequately the physical, chemical, and economic facts, and to apply them to a thoroughgoing improvement of plains agriculture, much new research needs to be undertaken in the various areas.

When the available known methods of erosion control are applied to each problem area on the basis of efficient land and water utilization, either a different list of methods results for each problem area, or a different relative importance of various methods is developed. This may be illustrated by comparing the outline of the conservation program in three adjacent farming areas of the region.

Problem area 2B, taking in the southern plains deep heavy wheatland soils, requires the following: (1) Water conservation by contour tillage supported by terracing solely for water conservation purposes to promote vegetative cover; (2) crop diversification with wheat, the major crop, and sorghum feed crops, the minor crop, in variable rotation guided by seasonal and soil conditions to maintain vegetation; (3) the conservation and gradual return of carbonaceous residues to the soil to prevent wind erosion and stimulate

Typical blown-out wheatfield resulting from loss of residue and from improper land use during the drought period. Portions of this field have been blown out to the subsoil, and sand drifts have formed in other areas.

nitrogen fixation; (4) marketing of small grains, and the utilization of feed grains and forages through small permanent or transient livestock units—depending upon availability of grazing-type land in the neighborhood—to stabilize the business; (5) feed storage facilities and the maintenance of a 2-year feed reserve to facilitate the conservative grazing of growing crops, stalk fields, and permanent pastures.

Problem area 3C, having medium-textured rolling plains soils, requires: (1) Contour tillage and terracing for the dual purpose of water-erosion prevention and water conservation to promote the continuity of vegetative cover; (2) the strip crop rotation of cotton to distribute effectively the vegetative cover, feed crops, and soil-building crops; (3) the conservation of fibrous carbonaceous residues for wind-erosion prevention and for fertility maintenance; (4) feed-storage facilities; the marketing of cotton and the utilization of feed grains and forages through small permanent livestock units; (5) the maintenance of 1-year feed reserve to facilitate the conservative management of grazing, stalk fields, growing crops, and pastures.

Problem area 5A, with medium-depth high-plains soils, requires the consistent use of erosion-resistant crops, either in solid planting or in strip planting if economic preferability demands the use of erosion non-resistant crop types; the regular return of crop residues to the soil, and the strict control of stalk field grazing.

It will be noted that surface-water control measures serve a single purpose in one instance, a dual purpose in another, and are not required at all in the third. Similarly, systematic rotation is used in one instance, variable rotation in another and continuous cropping in a third. Strip cropping is used occasionally in one area, regularly in another, and optionally in the third. The water management requirements also vary among the different grazing areas in similar fashion to that prevailing in the crop land areas.

In this manner the findings of research, interpreted through a clear understanding of the conservation objectives, are applied separately to the sixteen or more individual problem areas of the region.

WINDBREAKS HELP CONTROL

(Continued from p. 254)

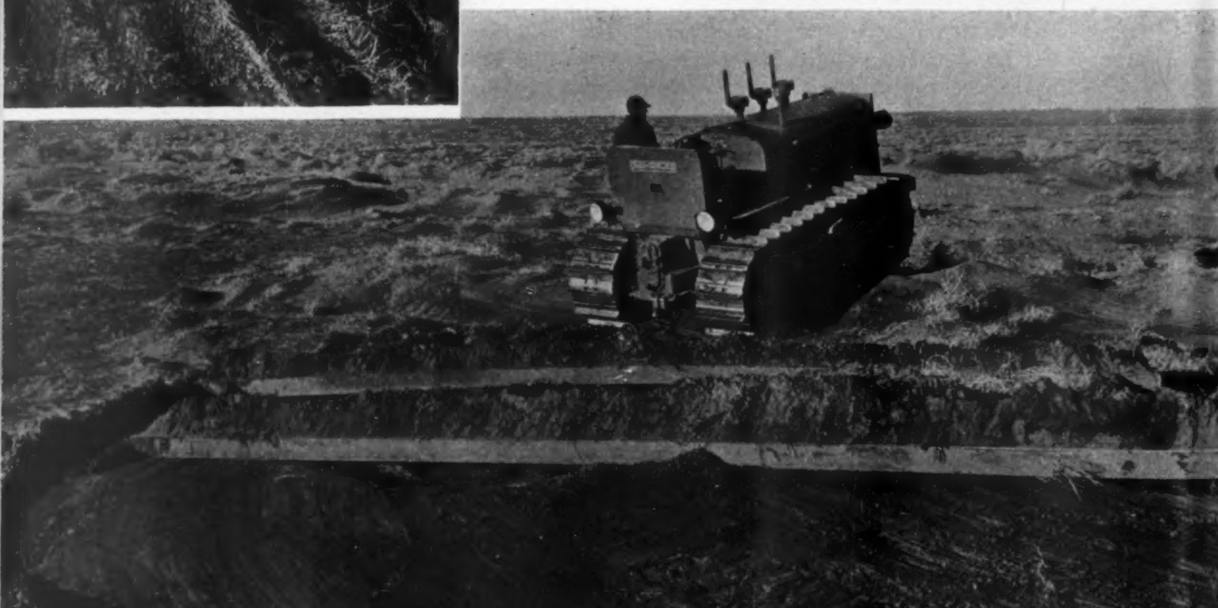
conditions—are cottonwood, American elm, ash, hackberry, locust, oak, Chinese elm, Osage orange, mulberry, Russian olive; and, for the border plantings, wild plum, chokecherry, lilac, tamarix and caragana. Among the evergreens the red cedar, western white spruce (Black Hills) and Colorado spruce, Austrian and western yellow pine are most valuable.

Conifers are effective for both winter and summer protection, but they are more difficult to establish than deciduous trees. A combination of the two is preferable, and such plantings produce the most satisfactory results.

Above: When Sudan or other grain sorghums are harvested, enough stubble is left to afford protection during the blowing season.

Left: This farmer has his field back under complete control. He is shown turning under the wheat stubble to provide protection during the next blowing season. He can continue in wheat production so long as conditions are favorable.

Below: The first step, leveling hummocks sufficiently to make cultivation possible. This farmer is doing the job by dragging heavy railroad irons behind a tractor.



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